Fetal Cell Phone Exposure: How Experimental Studies Guide Clinical Practice

Hugh S. Taylor, M.D.

Chair of Obstetrics, Gynecology and Reproductive Sciences

Yale School of Medicine

Cell Phones

- Use of cell phones has grown dramatically over the last twenty years.
- Operate at frequencies slightly higher than TV and FM Radio signals (Nonionizing).
- Analog and digital phones operate in the frequency range of 900 - 1800 MHz.
- The maximum powers of these phones are 2W and 1W (900 and 1800 MHz respectively). Average power are 1/8 of maximum.

S.A.R.

Specific Energy Absorption Rate

watts per kilogram

- Electromagnetic waves interacting with matter can be
  - Reflected
  - Absorbed
  - Transmitted
- Exactly what happens depends on
    - the **frequency of the electric field**
    - the **natural frequencies** of the atoms and molecules
- Microwaves emitted by mobile phone systems
    - Are absorbed by human tissue

Specific energy Absorption Rate (SAR)
watts per kilogram

- Measures **energy absorbed per kilogram per second.**
- **SAR** is a property of
  - an emitting device
  - in a particular position with respect to
  - an absorbing substance

Mobile phones communicate with base stations

- Macrocells - up to about 22 miles. Power output in tens of watts.
- Microcells - infill, airports, railway stations. Range of few hundred yards.
- Picocells - Sited inside buildings. Low power.

Thermal Effects

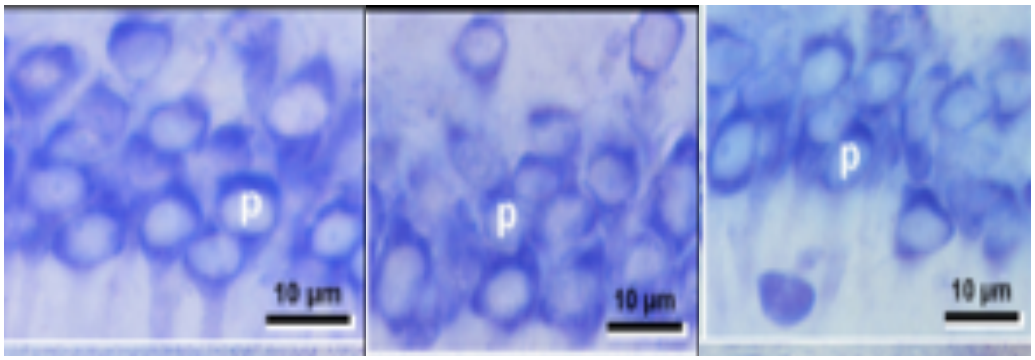
- Force produced by an electric field on charged objects (ions in the body) causes them to move, results in electric currents. Currents flowing through resistance of the material results in heating. Heat input causes increased blood flow for heat dissipation (equilibrium).
- Increase in brain temp by cell phones is estimated to be 0.1 C (to equilibrium).

Plausible Biological Effects of Cell Phone EM Radiation

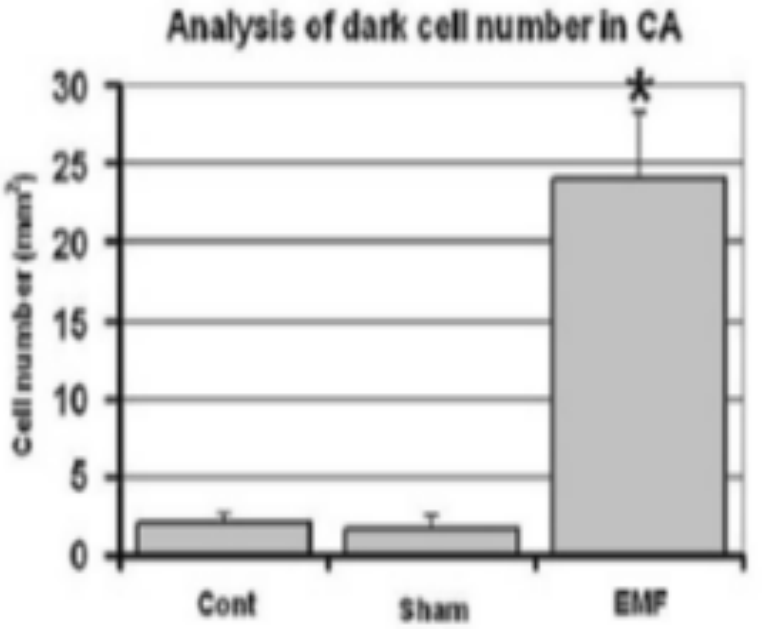
- Could fields induce cell polarization?
- Alter membrane potential?
- Could fields affect movement of ions through cell membrane channels?
- Does it increase free radical production?
- Do fields effect gene expression?
- Others?
- If any of these effects are real, do they result in an adverse health outcome?

900 MHz electromagnetic field exposure affects hippocampal pyramidal cells in adult female rats

1h/day x 28 days; 16 wk females



Control Sham Exposed

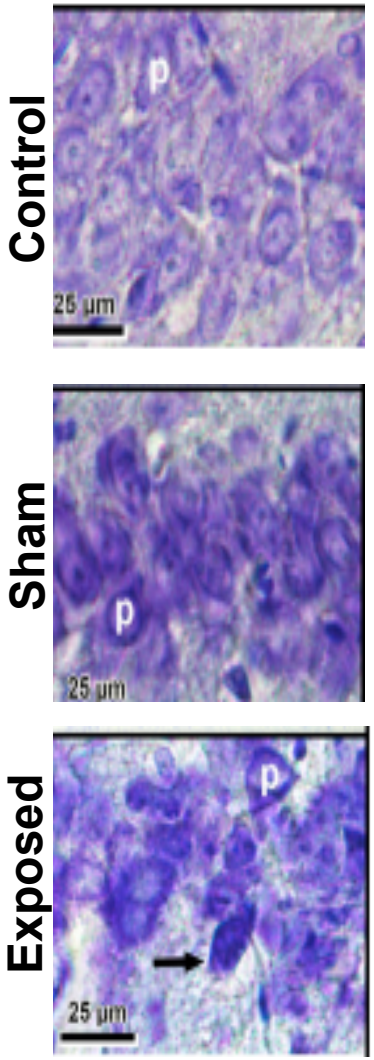


Significantly more dark cells compared with both the control and sham Mean±SEM *p < 0.01.

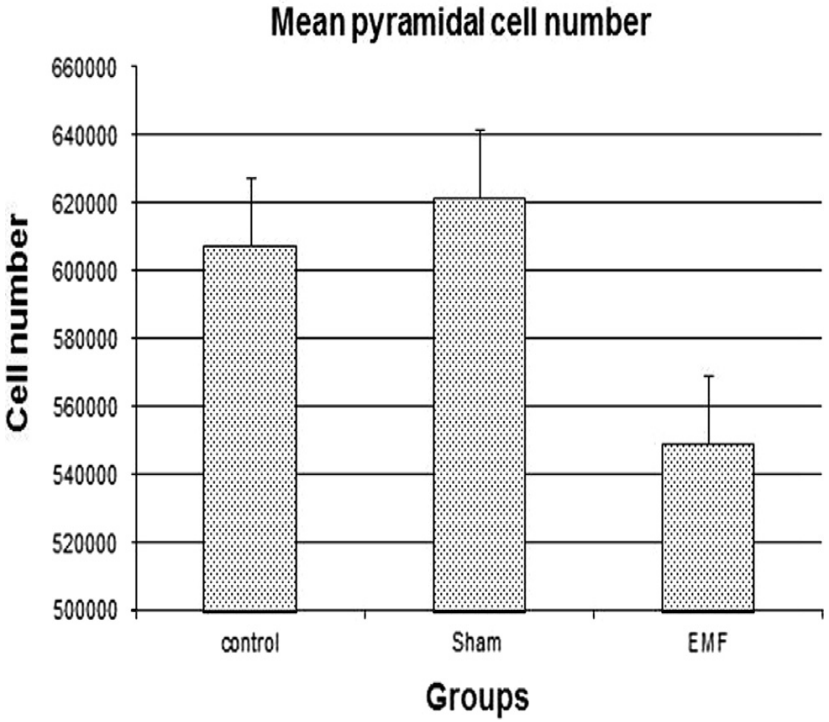
Postnatal EMF exposure caused a significant decrease of pyramidal cells in the Cornu ammonis of the EMF group.

Bas O, Odaci E, Kaplan S, Acer N (2009)

900 MHz electromagnetic field exposure affects hippocampal pyramidal cells in prepubescent male rats



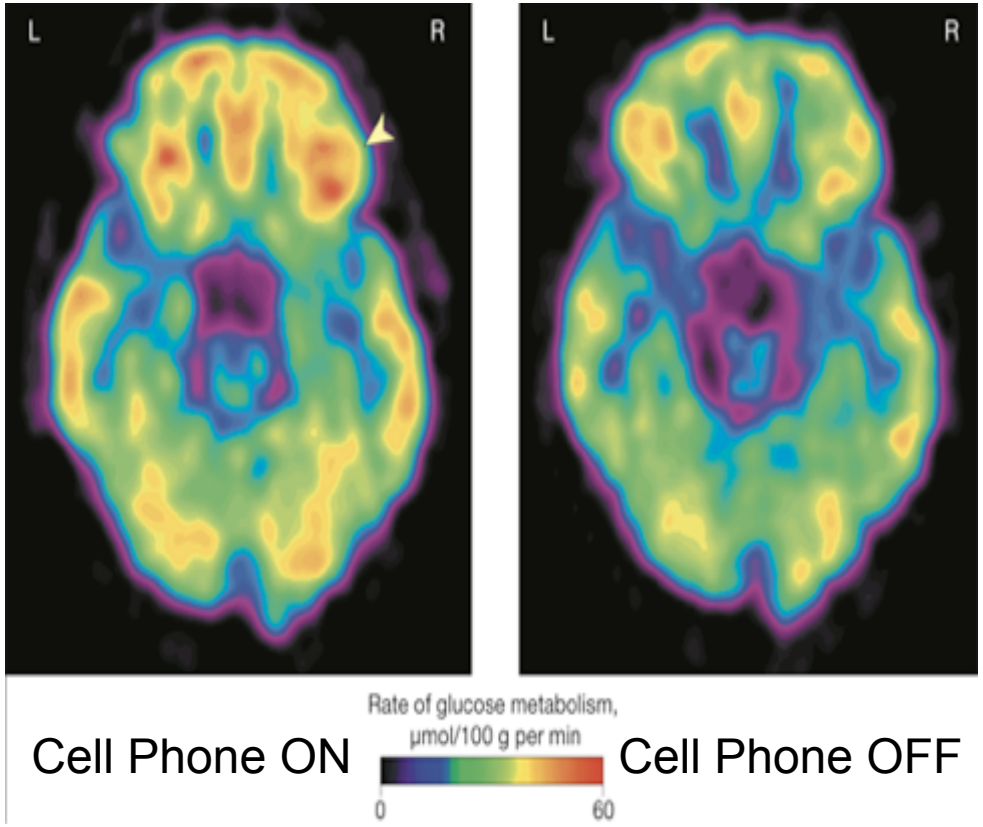
Exposure: 1h/day x 30 days; 8 wk males



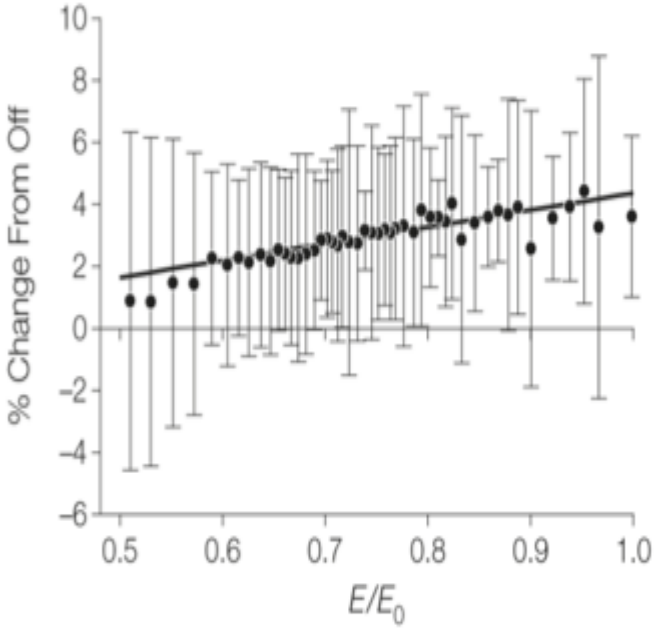
Lower mean number of pyramidal neurons in exposed group than in the control and sham.

Sahin A, Aslin A, Bas O, et al. (2015)

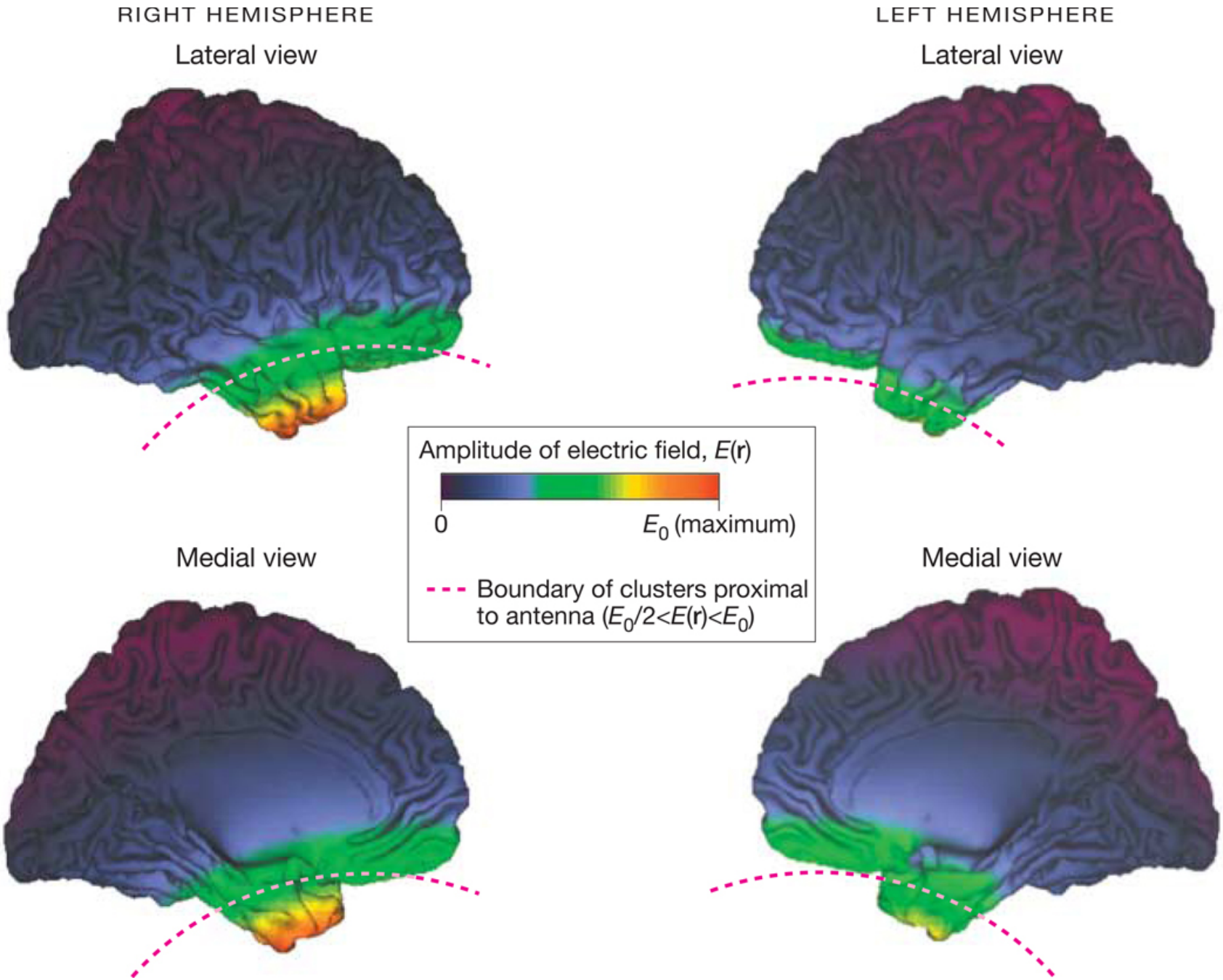
50 minutes with a cell phone turned on against the ear significantly alters cerebral glucose metabolism



Normalized glucose metabolism higher, at higher brain tissue doses



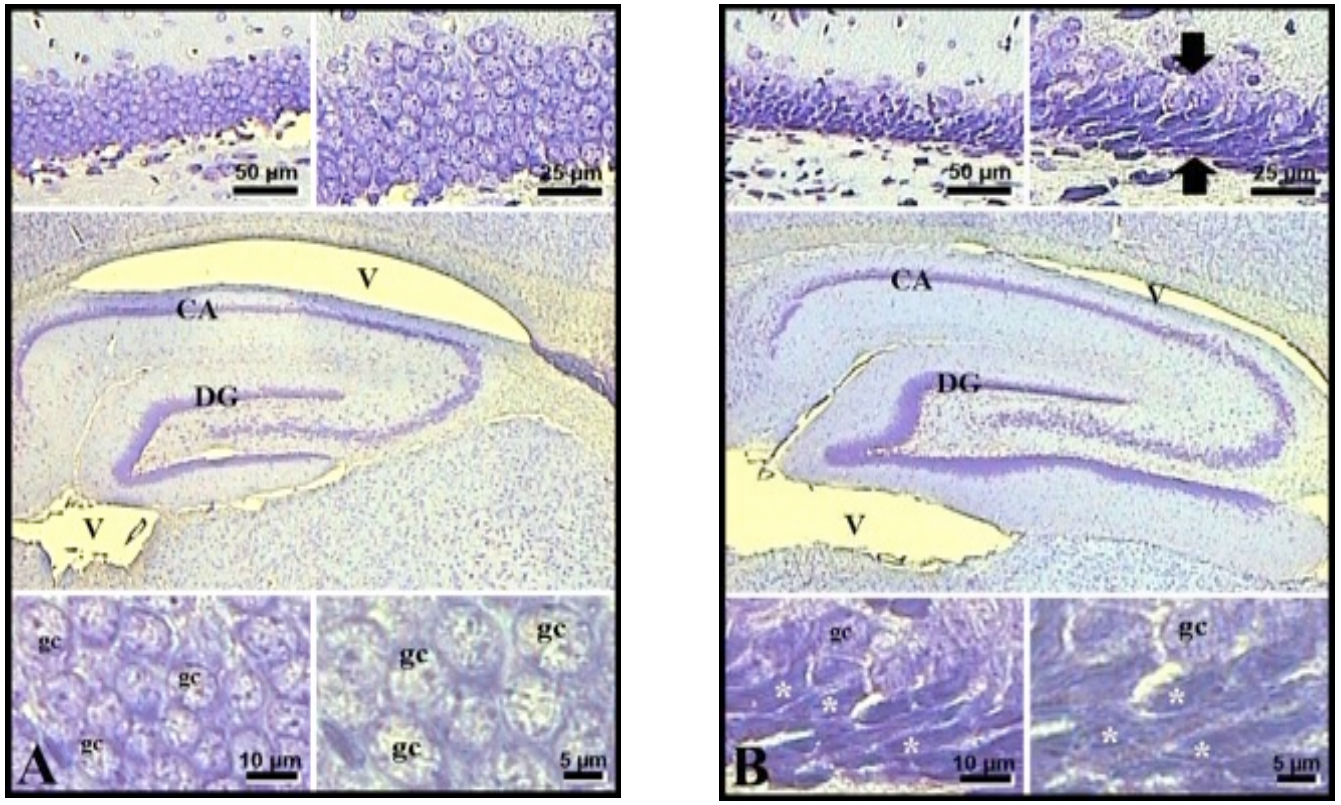
Volkow et al, JAMA, 2011, 305 (8): 808-813.


RIGHT HEMISPHERE
Lateral view
LEFT HEMISPHERE
Lateral view
Amplitude of electric field, E(r)
0
E0 (maximum)
Boundary of clusters proximal to antenna (E0/2<E(r)<E0)
Medial view
Medial view

Cell Phone Use During Pregnancy May be Harmful to the Fetus

Fewer, abnormal hippocampal granular cells in the dentate gyrus (DG) of newborn rats following prenatal 900 MHz EMF exposure

Control **Exposed**



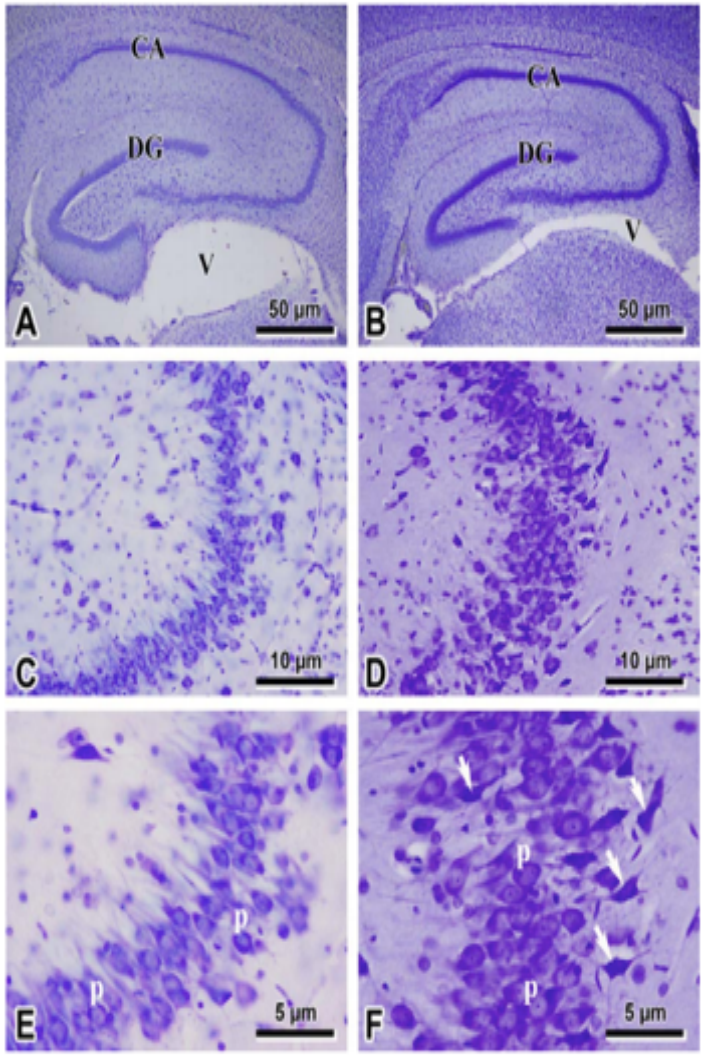
Representative photomicrographs and magnifications of the medial region of DG.

Control group granular cells normal; most in the EMF group abnormal, condensed.
(arrows - dark-blue cells interspersed among normal nerve cells).

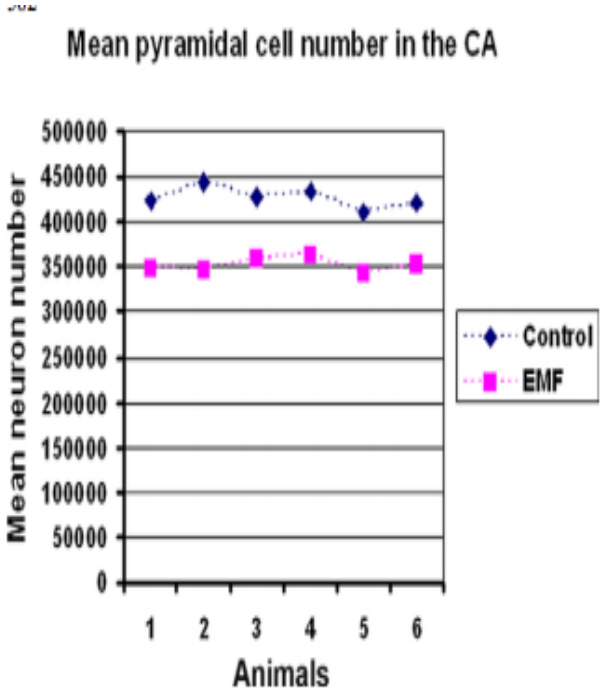
Odaci E, Bas O, Kaplan S. (2008)

Fewer pyramidal cells in rat pups' hippocampus with 900 MHz RF prenatal exposure (1h daily x 19 days)

Control **Exposed**



Hippocampus sections: More cells are an abnormal, with shrunken morphology following prenatal EMF exposure.



Significantly fewer pyramidal cells in the cornu ammonis with EMF exposure.

Bas O, E Odaci, H Mollaoglu, *et al*. (2009)

Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children

- Mothers were recruited to the Danish National Birth Cohort early in pregnancy.
- When the children of those pregnancies reached 7 years of age in 2005 and 2006, mothers were asked to complete a questionnaire regarding the current health and behavioral status of children, as well as past exposure to cell phone use.
- Mothers evaluated the child's behavior problems using the Strength and Difficulties Questionnaire.
- N=13,159

Divan et al Epidemiology: 2008,19(4);523-529

TABLE 2. Association of Prenatal and Postnatal Exposure to Cell Phone Use With Overall Behavioral Problems Score

	Postnatal Exposure					
	No		Yes		Prenatal Exposure[a]	
	Unadjusted OR	Adjusted OR (95% CI)[b]	Unadjusted OR	Adjusted OR (95% CI)[b]	Unadjusted OR	Adjusted OR (95% CI)[b]
Prenatal exposure						
No	1.0[c]	1.0[c]	1.25	1.18 (0.96–1.45)	1.0[c]	1.0[c]
Yes	1.77	1.58 (1.29–1.93)	2.16	1.80 (1.45–2.23)	1.74	1.54 (1.32–1.81)
Postnatal exposure[d]	1.0[c]	1.0[c]	1.26	1.18 (1.01–1.38)		

n = 12,068 with information about prenatal and postnatal exposure; n = 12,112 with information about prenatal exposure; n = 13,054 with information about postnatal exposure.

[a]OR for prenatal exposure adjusted for postnatal exposure.

[b]Adjusted for sex of child, age of mother, smoking during pregnancy, mother's psychiatric problems, and socio-occupational levels.

[c]Reference category.

[d]OR for postnatal exposure adjusted for prenatal exposure.

TABLE 3. Associations of Specific Behavioral Problems in Children With Prenatal and Postnatal Exposure to Cell Phone Use

	Prenatal Exposure Only		Postnatal Exposure Only		Both Prenatal and Postnatal Exposure	
	Unadjusted OR	Adjusted OR (95% CI)[a]	Unadjusted OR	Adjusted OR (95% CI)[a]	Unadjusted OR	Adjusted OR (95% CI)[a]
Behavioral problems						
Emotional	1.23	1.12 (0.97–1.30)	1.13	1.06 (0.92–1.23)	1.50	1.25 (1.07–1.47)
Hyperactivity	1.39	1.29 (1.08–1.53)	1.00	0.98 (0.82–1.17)	1.52	1.35 (1.12–1.63)
Conduct problems	1.29	1.21 (1.05–1.40)	1.06	1.02 (0.89–1.18)	1.69	1.49 (1.28–1.74)
Peer problems	1.36	1.27 (1.06–1.52)	1.11	1.08 (0.90–1.29)	1.51	1.34 (1.11–1.63)

Reference category is no prenatal or postnatal exposure to cell phone use.
[a]Adjusted for sex of child, age of mother, smoking during pregnancy, mother's psychiatric problems, and socio-occupational levels.

TABLE 5. Association of Characteristics of Mother's Cell Phone Use During Pregnancy With Overall Behavioral Problems Score in Children With Prenatal Exposure (n = 3322)

	No. (%)	Unadjusted OR	Adjusted OR (95% CI)[a]	Adjusted OR (95% CI)[a,b]
Times spoken per day				
0–1	1873 (56.4)	1.00[c]	1.00[c]	1.00[c]
2–3	777 (23.4)	1.49	1.33 (0.99–1.79)	1.31 (0.97–1.77)
4+	347 (10.4)	1.60	1.51 (1.02–2.22)	1.47 (1.00–2.18)
Missing	325 (9.8)	—	—	—
P for trend	—	0.28	0.61	0.62
Percentage of time turned on				
0	397 (12.0)	1.00[c]	1.00[c]	1.00[c]
<50	500 (15.1)	0.70	0.62 (0.35–1.11)	0.62 (0.35–1.10)
50–99	954 (28.7)	1.20	0.93 (0.58–1.48)	0.91 (0.57–1.45)
100	1427 (43.0)	1.43	1.09 (0.70–1.70)	1.06 (0.68–1.65)
Missing	44 (1.2)	—	—	—
P for trend	—	0.15	0.13	0.13

[a]Estimates adjusted for sex of child, age of mother, smoking during pregnancy, mother's psychiatric problems, and socio-occupational levels.
[b]Also adjusted for postnatal exposure to cell phones.
[c]Reference category.

Conclusions

- Exposure to cell phones prenatally—and, to a lesser degree, postnatally—was associated with behavioral difficulties such as emotional and hyperactivity problems around the age of school entry.
- These associations may be noncausal and may be due to unmeasured confounding. If real, they would be of public health concern given the widespread use of this technology.

Cell phone use and behavioural problems in young children.

- To see if a larger, separate group of DNBC children would produce similar results after considering additional confounders, children of mothers who might better represent current users of cell phones were analyzed. This 'new' dataset consisted of 28,745 children with completed Age-7 Questionnaires to December 2008.
- The highest OR for behavioral problems were for children who had both prenatal and postnatal exposure to cell phones compared with children not exposed during either time period.
- The adjusted effect estimate was 1.5 (95% CI 1.4 to 1.7).

Divan et al, J Epidemiol Community Health. 2012;66(6):524-9.

Controlled study of Fetal Radiofrequency Radiation Exposure From Cellular Telephones and Behavior in Adult Mice

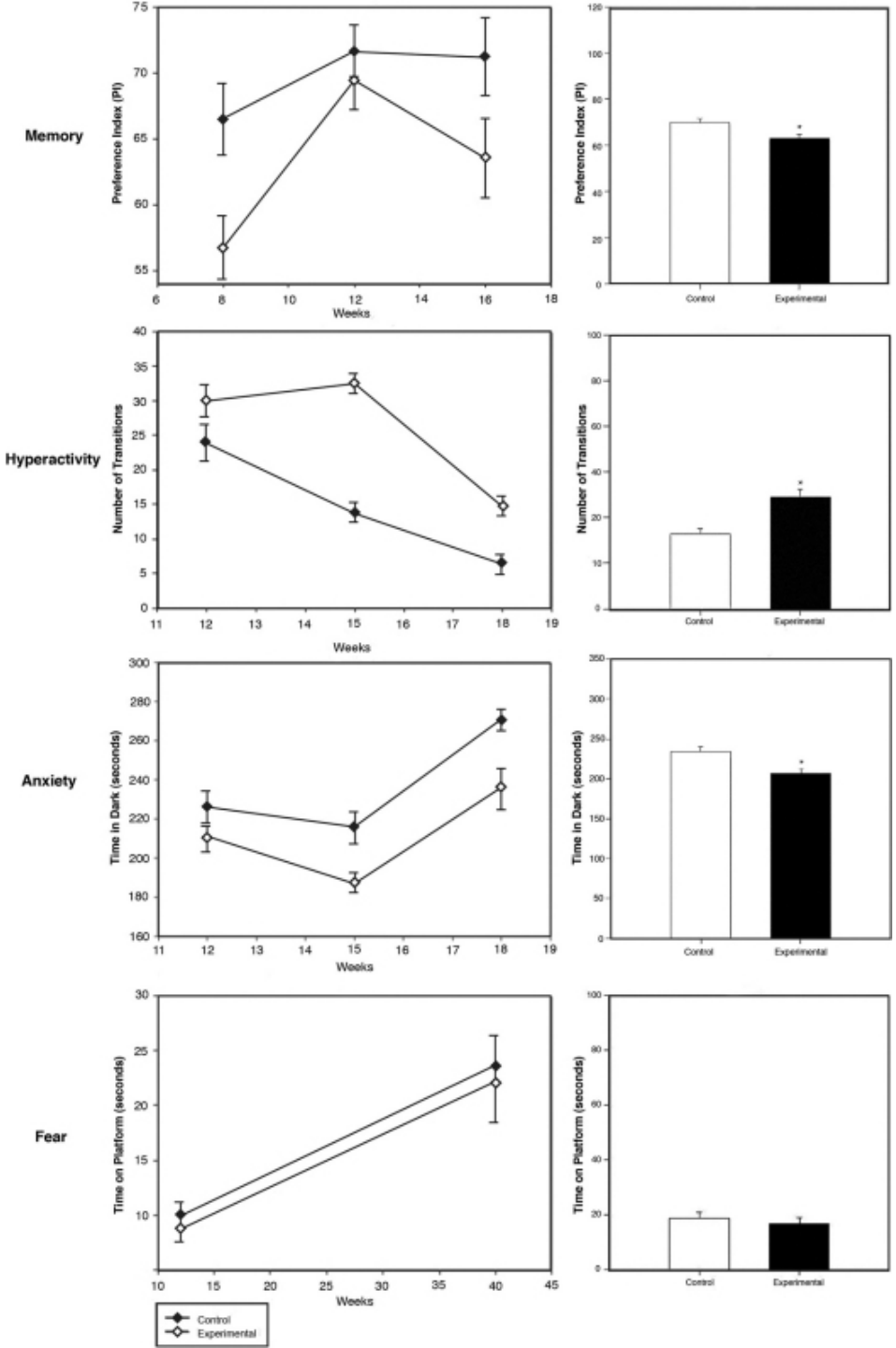
Fetal Radiofrequency Radiation Exposure From 800-1900 Mhz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice

Aldad et al, Scientific Reports. 2012; 2: 312.

Fetal Brain Programming

42 pregnant controls

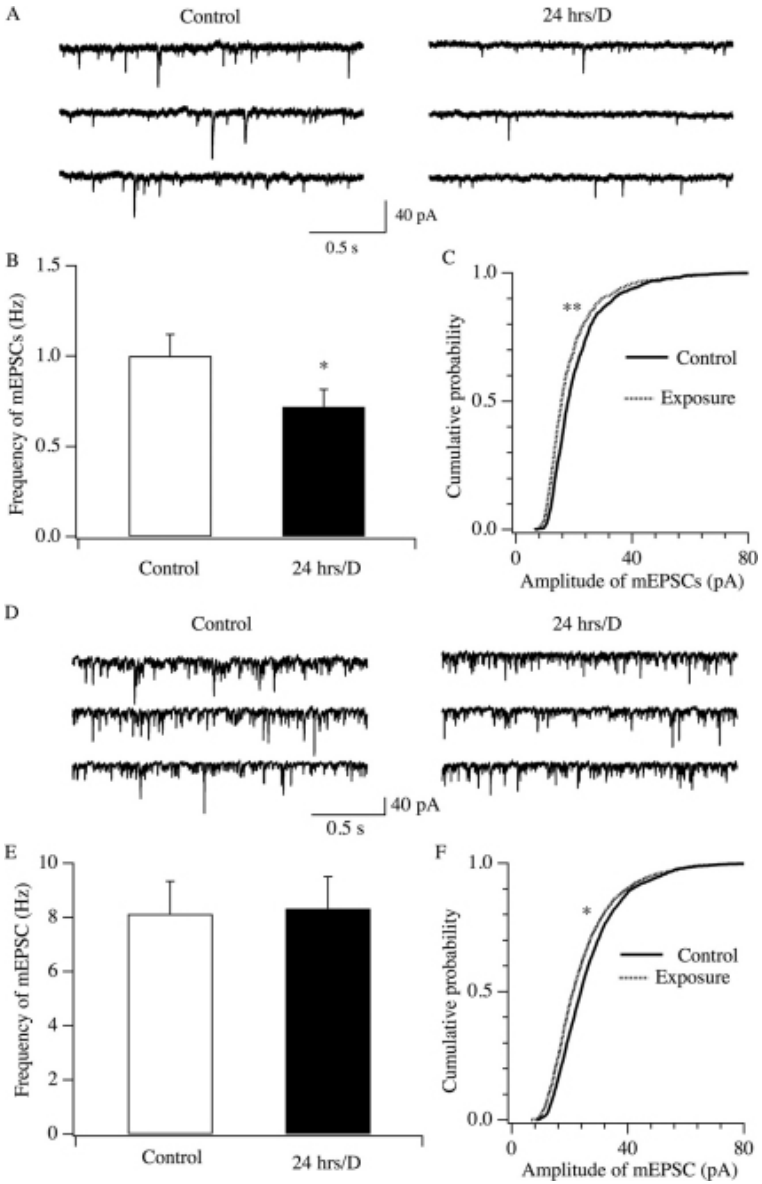
- A muted and silenced 800–1900Mhz cellular phones with a SAR of 1.6W/kg was used.
- The phones were positioned above each cage over the feeding bottle area at a distance of 4.5–22.3cm from each pregnant mouse.
- Mice exposed as a fetus were tested as adults.


Memory
Preference Index (PI)
Weeks
Control
Experimental
Hyperactivity
Number of Transitions
Anxiety
Time in Dark (seconds)
Fear
Time on Platform (seconds)

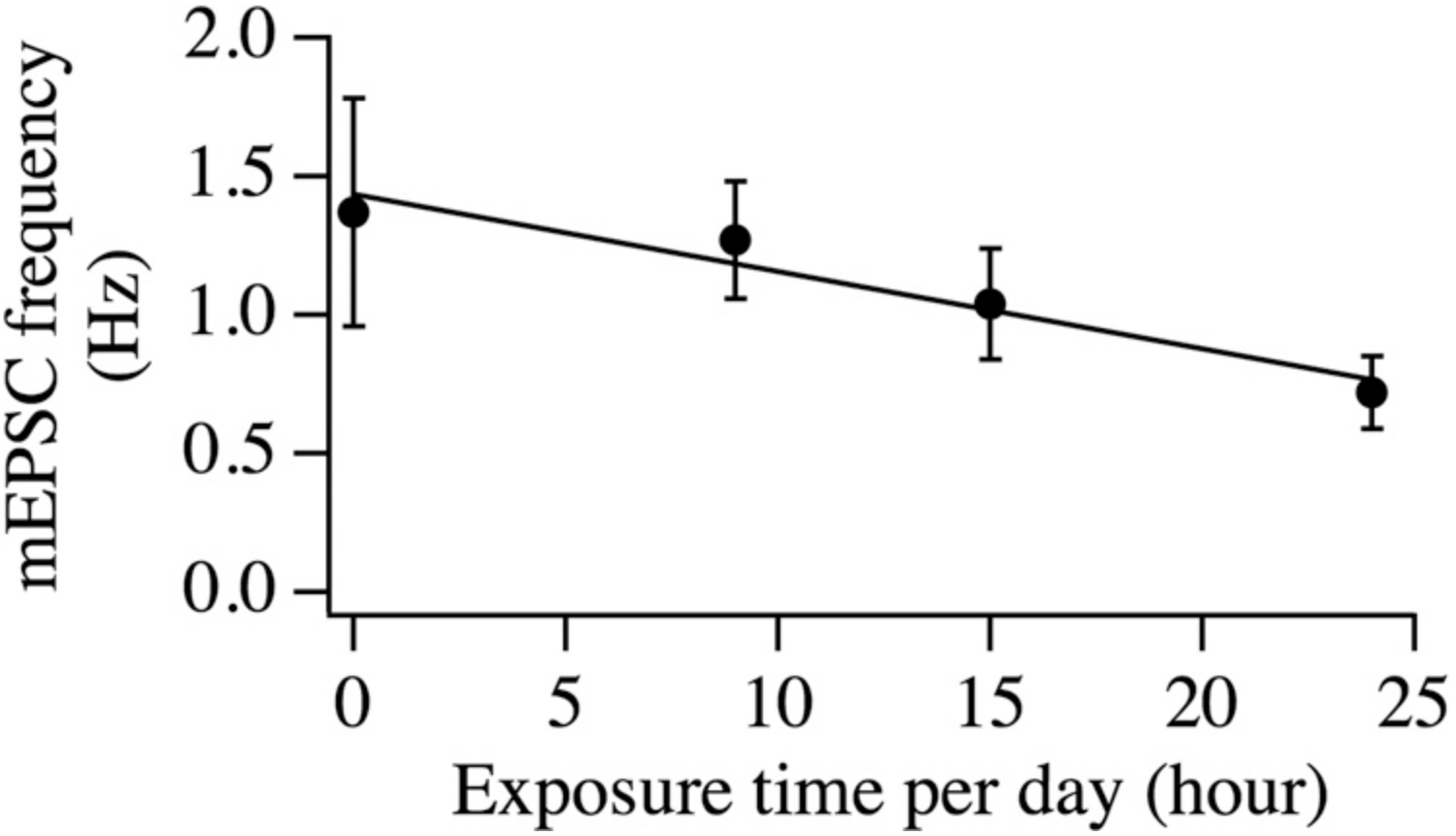
Definition

- Attention Deficit Hyperactivity Disorder (ADHD), sometimes called Attention Deficit Disorder (ADD), involves hyperactivity, difficulty paying attention and a tendency to act impulsively.

Altered Synaptic Efficiency



Diminished Effect with Decreased Exposure



No brain tumors

No effect of post-natal exposure

And its not just mobile phones!

- ‘WiFi’ Wireless Networking
- Bluetooth devices
- Wireless keyboards and mice
- DECT cordless phones
- Baby Monitors
- ‘Walkie Talkie’

- All involve electromagnetic waves in the radio and microwave part of the spectrum

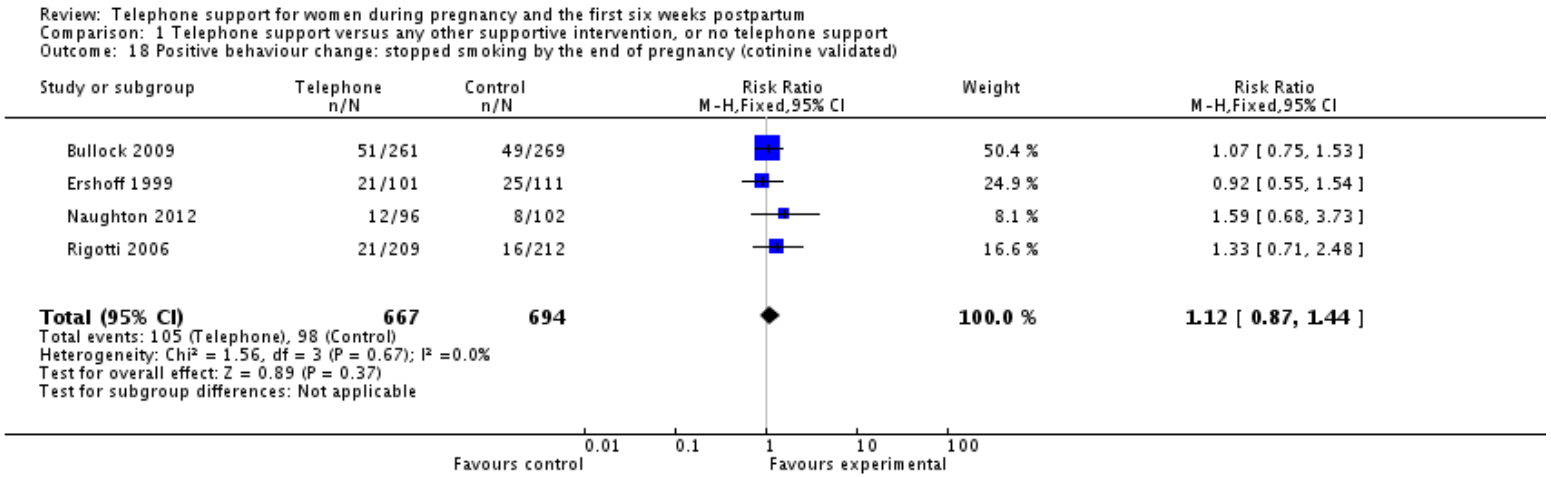
Mobile Phones : Comparison of handsets and base stations

	Power Watts	**Intensity** Watts per square metre	**Maximum SAR** Watts per kilogram
Handset	**1**	**200**	**About 1**
Base Station	**60**	**0.01**	**About 0.001**
Wi Fi	**0.1**	**< 0.01**	**About 0.0001**

Effectiveness of mHealth [cell phone] interventions for maternal, newborn and child health in low- and middle-income countries.

Lee et al, J Glob Health. 2016;6(1):010401.

Telephone support for women during pregnancy and the first six weeks postpartum



Cochrane Database of Systematic Reviews
18 JUL 2013 DOI: 10.1002/14651858.CD009338.pub2
http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD009338.pub2/full#CD009338-fig-00118

Broader Issue:

- What role do the fetal environmental exposures play in the health of the next generation?